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Description

Diagnostic system and method for a valve, especially a check
valve of a positive displacement pump

The invention relates to a diagnostic system as well as to a

5 diagnostic method for a valve, especially a check valve of a
positive displacement pump, in accordance with the preamble of
claim 1 or the preamble of claim 4.

In many areas of process control and energy technology the
fault-free operation of a system depends on the smooth

10 functioning of the control and check valves used. To avoid
cost-intensive, irregular interruptions to operation, damage to
valves should where possible be detected right at the outset,
that is before a failure of the valve can result in a shutdown
of the plant. For example defective valve seats result in

15 leakage flows which generate a wideband sound emission.
Recording and evaluation of the sound emission of a valve can
thus be used for early detection of valve damage. Since valve
faults can lead to damage and resultant high costs a diagnosis,
possibly with automatic recording and programmable evaluation

20 of the faults, is of great benefit. Statistical evaluations of
the diagnostic data can be used both for optimizing the
maintenance process and for timely replacement of a damaged
valve as well as for qualitative assessment and classification
by the valve manufacturer or for assessment of the suitability

25 of particular valves for different types of process.

A diagnostic system is known from DE 199 24 377 A1 for a valve
which can be actuated by a position controller via a drive,
which features a device for recording, storage and evaluation
of solid-borne sound spectra measured at the valve. To make an

30 especially reliable valve diagnosis possible a solid-borne
sound spectrum of recorded for a slightly open, intact valve

can be stored in the device for recording, storage and evaluation. For diagnosis a solid-borne sound spectrum recorded for a closed valve is compared to the spectrum stored and the similarity is employed as a criterion for the lack of seal of

5   the valve. The known diagnostic method has the disadvantage that an exact positionability of the closing element is required so that a comparison spectrum for a slightly open, intact valve can be recorded for simulation of a valve leakage. It is thus not applicable to a plurality of valve types, for

10   example check valves for positive displacement pumps.

A further diagnostic system is known from EP 0 637 713 A1 for regulation and cut-off valves. The sound level is measured during the operation of the valve with a solid-borne sound sensor. This is compared with the sound level previously

15   recorded for the good state for a new valve and stored as a reference value. If the deviation between current state and good state exceeds a predetermined limit value an alarm is triggered. This known method is associated with the following disadvantages:

20   The sound level measured in the good state is predominantly caused by plant noises which for example are coupled in via pipe connections. These can change after calibration. If they become larger there is a possibility of a false alarm being triggered. If the plant noises become smaller during the course

25   of operation this leads to a reduction in measurement sensitivity since the threshold value predetermined was too high. In addition the measurement of the sound level in the good state involves additional expenditure during commissioning. With operating conditions which vary greatly for

30   the valve under investigation the diagnostic method cannot be employed because the plant sounds are heavily dependent on the operating conditions. For check valves of positive displacement

pumps especially the method cannot be used under these circumstances since measurements have shown that the system noise always depends on the operating pressure and this rises by around 20 dB if there is a change in pressure from 5 to 50 bar.

The underlying object of the invention is to create a diagnostic system and a diagnostic method which react less sensitively to changes in the noise of the system.

To achieve this object the new diagnostic system of the type mentioned at the start has the features mentioned in the preamble of claim 1 or the diagnostic method has the features mentioned in the preamble of claim 4. Advantageous developments are described in the dependent claims.

For a reliable detection of a leakage the leakage noise for a closed valve and the leakage noise for an open file are recorded almost simultaneously and compared with one another. The two measurement times can be all the closer to one another the shorter the gap is between the two states "valve open" and "valve closed". In the special case of an application of the diagnostic system to check valves in oscillating positive displacement pumps the valves are periodically opened and closed. Since the two check valves assume it precisely opposite states at specific times the leakage noise can be recorded at one valve while at precisely the same time the plant noise is recorded at the other valve. The noises can be assigned to the relevant valve state in a simple way by suitable signal processing. In principle the diagnosis can however be performed in this case with just one solid-borne sound sensor which then records the leakage noise and the plant noise in the closed or open state of the same valve respectively in chronological order. However in this case the new diagnostic system has the advantage that it is largely insensitive to gradual changes in

operating conditions.

Correspondingly the new diagnostic system and a new diagnostic method can be applied for valves in piston compressors which operate in accordance with a largely similar principle.

5   The diagnostic system has an especially low sensitivity to wide variations in operating conditions if the first value and the second value of the characteristic variable which are compared with each other are determined on the basis of the sound signal last recorded in the closed or the open state. In this case it
10 can be assumed that the plant's noises in the intervening period have in any event only changed slightly and thereby barely affect the diagnosis result in any way.

In an application of the system to diagnosis of a check valve of a positive displacement pump it is advantageously sufficient
15 to have especially low expenditure for measuring system components if the evaluation device is embodied such the respective state of the valve can be determined by it on the basis of the recorded sound signal. In this case no further means for recording the position of the closing element is
20 necessary. The system can make do with just one sound recorder for a measuring point.

The invention, along with its embodiments and advantages, is explained in greater detail below with reference to the drawings in which an exemplary embodiment of the invention is
25 shown.

The Figures show:

Figure 1   a positive displacement pump with a diagnostic system
            with two solid-borne sound sensors,

Figure 2   a positive displacement pump with a diagnostic system

with one solid-borne sound sensor,

Figure 3   Waveforms of solid-borne sound signals recorded at
          the positive displacement pump according to Figure 1
          and

5   Figure 4   sound levels calculated on the basis of the waveforms
            shown in Figure 3.

Figures 1 and 2 each show a positive displacement pump along
with its basic layout. The same parts are identified by the
same reference symbols in the two Figures. The functional
10 principle of a positive displacement pump is thus explained
below with reference to the example shown in Figure 1. A piston
1 is moved alternately left and right in a cylinder 4 by a
crankshaft 2 with a connecting rod 3. This produces a variable
volume 5 in cylinder 4. Check valves 8 or 9 are arranged in an
15 inlet 6 and in an outlet 7 to this volume 5 respectively. These
check valves are frequently also referred to as inlet or outlet
valves. If the volume 5 reduces as shown in the phase depicted
in Figure 1, check valve 9 opens and a medium to be delivered
flows out to the outlet 7. At the same time valve 8 is closed.
20 With an enlargement of the volume 5 on the other hand, valve 8
opens so that the medium can flow into the inside of cylinder
4. The valve 9 closes the outlet 7 and thereby prevents
flowback of the medium already delivered. One valve is thus
closed and the other is opened respectively in both delivery
25 phases. The change between these states occurs cyclically and
with a largely constant duration.

Figure 1 further shows a diagnostic system with two sensors 20
and 21 which are arranged at valve 8 or 9 respectively. In an
evaluation device 22 the solid-borne sound signals recorded
30 with sensors 20 and 21 are initially bandpass filtered with a
filter 23 or 24 respectively. This filtering especially

eliminates the impact noises which occur when the closing
element hits the valve seal seat. In this filtering salient
resonant frequencies of the system in which the valves are
located can additionally be filtered out. The filtered sound

5   signal of valve 9 is fed to a device 25 for determining the
valve state in which it is also established whether the valve 9
is currently closed or open. In the open state the solid-borne
sound sensor 21 essentially delivers the plant noise since the
medium can flow freely through valve 9 and thereby only a low

10 noise level is created by the flow. If on the other hand valve
9 is closed in another delivery phase, the sound signal
recorded by the sensor 21 is predominantly caused for a
defective valve by the leakage flow which is overlaid on the
plant noise. For example, by means of auto correlation, device

15 25 detects the duration of the cyclic state transition and the
relevant delivery phase. The further evaluation of the signals
is undertaken in a suitable way synchronized to the delivery
phases. From the filtered sound signals of the sensor 20 and 21
the sound level for the closed valve 8 or the open valve 9 is

20 subsequently calculated in the downstream devices 26 or 27. The
two calculated sound levels are compared with each other by a
device 28. In this case the sound level of the open valve acts
as a reference level. It is thus subtracted from the sound
level of the closed valve 8. The difference between the two

25 sound levels thus created is compared in a comparator 29 with a
predeterminable threshold value 30. If the difference exceeds
the predeterminable threshold value 30, the comparator 29
creates an alarm signal 31 which is passed on to a control
station, which is omitted from the diagram for reasons of

30 clarity, so that suitable measures for rectifying the fault can
be initiated.

Instead of the device 25 for determining the valve state, this
state could be recorded in an alternative to the exemplary

embodiment shown by additional sensors. For example the valve
state could be recorded by a position generator as are normally
used with control valves. Since however the valve state can
already be determined on the basis of the sound signal itself,
5 no additional sensors are required for determining the valve
state.

A further alternate embodiment is shown in Figure 2. Here only
one sensor 40 is used for solid-borne sound, of which the
recorded sound signal is processed in an evaluation unit 41. A
10 filter 42 and a device 43 for determining the valve state can
be embodied in the same way as filter 24 and the device 25
already described with reference to Figure 1. The same applies
to calculating the sound level from the filtered sound signal
in a device 44. As well as the value of the sound level being
15 fed directly to the comparison device 45 this value is now also
fed to a delay unit 46 in which the value stored and delayed by
a half-period is output. The currently calculated sound level
which, for closed valve 8, essentially stems from the leakage
noise, is thus compared with a stored value of the sound level
20 in the device 45 which was determined a half-period before,
thus corresponds to the sound level for open valve 8 and was
predominantly triggered by the plant noise. The difference
between the current sound level and the stored reference level
is again fed to a comparator 47 which compares this difference
25 with a predeterminable threshold value 48 and creates an alarm
signal 49 if this threshold is exceeded. This embodiment has
the advantage that the second sensor for solid-borne sound can
be dispensed with.

The evaluation units 22 and 41 shown by function blocks with
30 reference to Figures 1 and 2 are in practice implemented by a
microprocessor circuit with a suitable evaluation program.
Implementation with similar modules is of course possible in

principle.

Figure 3 shows waveforms 50 and 51 of filtered sound signals,
such as can be recorded for example at an intact valve 8
(Figure 1) and a defective valve 9 (Figure 1). The time in

5   seconds is plotted on the abscissa, the Amplitude U1 of the one
sound signal and the amplitude U2 of the other sound signal
respectively in mV are plotted on the ordinates. The sound
signals have an essentially periodically repeating waveform. A
period begins for example with a delivery phase P1 in which the

10   defective valve 8 is open and the intact valve 9 is closed.
Because of the leakage noise the sound amplitude U1 measured at
valve 8 is considerably higher than that at valve 9. In the
other delivery phase P2 in which the intact valve 9 is closed
and the defective valve 8 is open, there is practically no

15   leakage flow in the intact valve 9 and both signal waveforms
approximately correspond to the plant noise. After the end of
the delivery phase P2 the next period begins with a further
delivery phase P1. Because of this periodicity it is possible
in a simple manner to determine the relevant valve state on the

20   basis of the sound signal recorded.

Figure 4 shows associated waveforms 60 and 61 of the calculated
sound levels L1 and L2, which are entered on the two ordinates
in dB. This Figure shows the same periods of time as those
already shown in Figure 3. In the delivery phase P1 the sound

25   level L1 for the defective valve 8 (Figure 1) is significantly
greater than the sound level L2 of the intact valve 9 (Figure
1) which serves here as reference level. The difference thus
exceeds the predeterminable threshold value 30 (Figure 1) and
an alarm signal 31 (Figure 1) for indicating a defective valve

30   is output. In delivery phase P2 on the other hand the
predeterminable threshold value is not exceeded by the
difference between the two sound levels L1 and L2. The valve 9

is thus recognized as intact.

On the basis of these waveforms it can be clearly seen that an
advantage of the new diagnostic system and method is that the
evaluation adapts in a "self-learning" way to the existing
5 system conditions in each case, since in each operating cycle
of the valve a reference value and a measurement value are
calculated. This simplifies parameter setting for the
evaluation device and the diagnostic system can advantageously
be used for wide variations in system noise. Only one solid-
10 borne sound sensor is also needed for a diagnosed valve in this
case. The relevant state of the valve, whether open or closed,
can be easily determined on the basis of the recorded sound
signal without additional measuring devices.